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FIELD EXPERIMENTS WITH COMMERCIAL FERTILIZERS.

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BULLETIN

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OHIO AGRICULTURAL EXPERIMENT STATION.

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FIELD EXPERIMENTS WITH COMMERCIAL AND OTHER FERTILIZERS IN 1892.

[BY C. E. THORNE AND J. FREMONT HICKMAN.]

The general plan of these experiments has been described in previous issues of this bulletin.*

Briefly stated, a tract of uniform land is divided into plots containing one-tenth or one-twentieth acre each; the plots are 16 feet wide and are separated by alley-ways 2 feet wide. Under every second alley-way a tile drain is laid In the case of the wheat plots the soil is clay, lying upon the bowlder clay of the drift and that upon Huron shale at a depth of 15 to 20 feet. It was formerly covered with forest, in which beech and elm predominated, and was wet and heavy before being drained. The plots on which corn and oats are grown have a gravel sub-soil, which gives partial drainage.

Twenty-two tenth-acre plots are devoted to the continuous culture each of wheat, corn and oats, each plot receiving the same treatment each year. Table 1 gives the order in which the plots are arranged, the quantity and cost per acre of fertilizer applied to each plot, and the quantity and cost per acre of essential ingredients contained. The cost is computed on the basis of the present price per ton in eastern markets, with five dollars per ton added for freight.

*Vol. III, 1890, p. 20; Vol. IV, 1891, p. 58; Vol V, 1892, p 35.

TABLE 1.—FERTILIZERS ON WHEAT, CORN AND OATS GROWN CONTINUOUSLY.—Quantity and cost per acre.

Plot No.	Fertilizers.	Quantity.	Essential Ingredients.			Cost.
			Nitrogen	Phos. acid	Potash	
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	
1	Unfertilized					
2	Superphosphate[1]	320		50		$4 00
3	Muriate of potash	80[4]			40[4]	2 00
4	Unfertilized					
5	Nitrate of soda	160[2]	25[2]			5 20
6	Nitrate of Soda Superphosphate	160[2] 320	25[2]	50		9 20
7	Unfertilized					
8	Superphosphate Muriate of Potash	320 80[4]		50	40[4]	6 00
9	Nitrate of Soda Muriate of Potash	160[2] 80	25[2]		40	7 20
10	Unfertilized					
11	Superphosphate Muriate of Potash Nitrate of Soda	320 80[4] 320	25[2]	50	40[4]	11 20
12	Superphosphate Muriate of Potash Nitrate of Soda	320 80 320	50	50	40	16 40
13	Unfertilized					
14	Superphosphate Muriate of Potash Nitrate of Soda	320 80[4] 480[3]	75[3]	50	40[4]	21 60
15	Superphosphate Muriate of Potash Sulphate of Ammonia	320 80 120	25	50	40	12 40
16	Unfertilized					
17	Dissolved S. C. Rock Muriate of Potash Nitrate of Soda	300 80[4] 160[2]	25[2]	45	40[4]	9 75
18	Thomas Slag (ground) Muriate of Potash Nitrate of Soda	300 80[4] 160[2]	25[2]	60	40[4]	10 85
19	Unfertilized					
20	Barnyard manure	8 tons	75	25	50	
21	Linseed oil-meal	1000	50	20	15	12 00
22	Unfertilized					

[1] Dissolved bone black.
[2] 480 and 75 pounds in 1888.
[3] 160 and 25 pounds in 1888.
[4] 160 and 80 pounds previous to 1892.

Stated in another form, plots 11, 15, 17 and 18 of this experiment each receive at the rate of 520 to 560 pounds per acre of a fertilizer containing about 5⅓ to 6 per cent. ammonia (ammonia being about 80 per cent. nitrogen), 8 to 9 per cent. available phosphoric acid and 7 to 7¾ per cent. potash. On plot 6 the same quantities of nitrogen and phosphoric acid are used, but by omitting the potash the percentages are changed to the equivalent of 6⅓ per cent. ammonia and 10½ per cent. phosphoric acid.

FERTILIZERS ON WHEAT GROWN CONTINUOUSLY ON THE SAME LAND.

This is the fourth successive crop of wheat grown on these plots. The field was in clover in 1887; it was drained in the spring of 1888, and the first crop was sown in the fall of that year. Immediately after a crop is removed the ground is plowed to the depth or 8 or 9 inches, and it is rolled and harrowed six or seven times between plowing and seeding, the surface being reduced to the condition of a garden and no weeds being allowed to grow.

The fertilizers are spread broadcast, just before drilling the wheat, except the nitrate of soda. This is a coarse, easily soluble salt, and to apply it all in the fall would involve the leaching away of the greater part of it before the plant could make use of it.

In 1890 it was all sown in the spring, about the middle of April. For the crop of 1891 the application was divided, half being sown in the fall and half in April. For the crop of 1892 dried blood was used in the fall, at the rate of forty pounds per acre, and nitrate of soda was sown in April in quantity sufficient to bring the total application up to the desired amount.

We have not discovered that the fall application, whether of nitrate or dried blood, has been any advantage.

In the crops of 1890 and 1891 the nitrate of soda produced a very marked effect on the growth of the plant, producing a dark green, rank growth of foliage. This effect was less marked this season, possibly because of the constant rains. Where nitrate and superphosphate were used in combination the wheat lodged badly, both in 1891 and 1892. Where they were used separately the tendency to lodge was not so great, and where nitrate was used in combination with Carolina rock or Thomas slag, instead of bone superphosphate, the wheat stood fairly well.

It would seem that the nitrate and superphosphate are equally responsible for throwing the wheat down.

The effect of superphosphate in stimulating an early and heavy growth of straw has been as marked this year as in previous seasons. The superphosphate plots could be distinguished within a few weeks after seeding, and their superior growth was more and more manifest until the wheat had headed out. Before harvest good judges estimated

the increased product of grain on these plots at from five to ten bushels per acre. The result of the harvest is given in table II and III, together with those of the three preceding harvests, and the average results of the four years' experiments.

[In these and subsequent tables the increase for the fertilized plots has been calculated on the assumption that if the yields of two neighboring unfertilized plots, 1 and 4, for example, were 25 and 28 bushels, respectively, the unaided yield of the fertilized plots between, 2 and 3, would have been 26 and 27 bushels. The "average yield of unfertilized plots" is given in each table for general comparison, but is not used in calculating the increase.]

TABLE II.—FERTILIZERS ON WHEAT FOUR YEARS IN SUCCESSION.

Yield and increase of GRAIN *in bushels per acre.*

Plot No.	Fertilizers.	Yield per acre.					Increase or decrease (—) per acre.					Plot No.
		1889.	1890.	1891.	1892.	Average.	1889.	1890.	1891.	1892.	Average.	
1	None	50.5	31.9	31.8	26.2	35.1						1
2	Superphosphate (dissolved bone-black)	50.2	35.6	29.3	31 2	36 6	2.9	3 7	—2.6	4.7	2.2	2
3	Potash (muriate)	47.5	32.1	30.2	28.2	34.5	3.5	0.3	—1.7	1 3	0.8	3
4	None	40.8	31.8	32.0	27.2	33.0						4
5	Nitrate of soda (1)	40.0	36.5	33.7	27.9	34.5	—3.0	4.3	0.6	0 2	0 5	5
6	Nitrate and superphosphate (1)	40 8	38 6	31 2	28 9	34 9	—4 5	6 0	—3.0	0.8	—0 2	6
7	None	47.5	33.0	35.3	28.6	36.1						7
8	Superphosphate and potash	41.6	36.4	30.5	30.2	34.7	—4.7	3.6	—3.4	1.7	—0 7	8
9	Nitrate and potash (1)	45.6	36 8	33 4	29.1	36.2	0.4	4 2	0 8	0 8	1 6	9
10	None	44.0(3)	32.4	31.2	28.1	33.9						10
11	Superphosphate, potash and nitrate 160 (1)	49.5	36.9	28.8	29.1	36.1	5.4	5.3	—2.5	1.4	2.5	11
12	Superphosphate, potash and nitrate 320	49.3	35.7	29.7	29 2	36.0	5.2	5.0	—1.7	2.0	2.6	12
13	None	44 2	29.9	31.5	26 8	33.1						13
14	Superphosphate, potash and nitrate 480 (2)	47.0	34.9	28.8	29.2	35.0	4.9	4.2	—2.5	2.1	2.4	14
15	Superphosphate, potash and ammonia	47.0	33.8	29.8	30 4	35.2	7 1	2.2	—1.2	3.0	2.7	15
16	None	37 8	32.4	30 8	27 8	32.2						16
17	Rock phosphate, potash and nitrate (1)	40.0	37.4	33.2	31.1	35.4	1.3	5.5	2.2	4.1	3.3	17
18	Slag phosphate, potash and nitrate (1)	39.3	37.3	31.7	31.6	35.0	—0 3	5.8	0.4	5.4	2.8	18
19	None	40.5	31 0	31.5	25.4	32.1						19
20	Barnyard manure	44.5	34.7	27.3	25.4	33.0	5.3	5.2	—2.7	1.1	2.2	20
21	Linseed oil meal	38.7	33.9	34.7	27.5	33.7	0.7	5.9	6.1	4.2	4.3	21
22	None	36.7	26.5	27.1	22 2	28 1						22
	Average of unfertilized plots	42.8	31.1	31.4	26.5	33.0						
	Average increase from fertilizers						1.7	4.4	—0.8	2.3	1.9	

(1) 480 pounds nitrate in 1889. (3) Estimated.

(2) 160 pounds nitrate in 1889.

TABLE III.—FERTILIZERS ON WHEAT FOUR YEARS IN SUCCESSION.

Yield and increase of STRAW *in pounds per acre.*

Plot No.	Fertilizers.	Yield per acre.					Increase or decrease (—) per acre.					Plot No.
		(3) 1889.	1890.	1891.	1892.	Average.	1889.	1890.	1891.	1892.	Average.	
1	None	4,070	3,602	4,540	3,015	3,807						1
2	Superphosphate (dissolved bone-black)	4,208	3,885	4,995	4,265	4,338	264	390	642	1,372	667	2
3	Potash (muriate)	3,850	3,062	3,740	3,190	3,461	32	— 327	— 427	418	— 75	3
4	None	3,692	3,282	3,980	2,650	3,401						4
5	Nitrate of soda (1)	3,560	3,930	3,980	2,710	3,545	— 251	630	— 83	— 13	70	5
6	Nitrate and superphosphate (1)	3,512	4,385	5,330	3,830	4,264	— 419	1,064	1,183	1,053	715	6
7	None	4,050	3,340	4,230	2,870	3,622						7
8	Superphosphate and potash	3,304	4,152	4,570	3,625	3,913	— 563	703	557	778	369	8
9	Nitrate and potash (1)	4,504	3,852	4,395	2,990	3,935	821	294	598	167	470	9
10	None	3,500	3,667	3,580	2,800	3,387						10
11	Superphosphate, potash and nitrate 160 (1)	4,270	4,725	5,675	4,390	4,765	754	1,250	2,047	1,582	1,409	11
12	Superphosphate, potash and nitrate 320	4,262	4,835	5,965	4,360	4,855	730	1,551	2,298	1,543	1,530	12
13	None	3,548	3,092	3,710	2,825	3,294						13
14	Superphosphate, potash and nitrate 480 (2)	3,920	4,592	5,820	4,235	4,642	344	1,428	2,280	1,447	1,375	14
15	Superphosphate, potash and ammonia	3,920	3,720	4,660	3,860	4,040	316	485	1,290	1,108	800	15
16	None	3,632	3,307	3,200	2,715	3,213						16
17	Rock phosphate, potash and nitrate (1)	3,460	4,175	4,860	3,720	4,054	— 153	987	1,607	1,090	883	17
18	Slag phosphate, potash and nitrate (1)	3,542	4,312	4,800	3,870	4,131	— 49	1,243	1,493	1,325	1,003	18
19	None	3,570	2,950	3,360	2,460	3.085						19
20	Barnyard manure	4,030	3,850	4,810	3,110	3,950	770	991	1,645	787	1,048	20
21	Linseed oil-meal	3,618	3,775	4,670	2,835	3,724	668	1,007	1,700	648	1,006	21
22	None	2,640	2,677	2,775	2,050	2,535						21
	Average of unfertilized plots	3,588	3,240	3,672	2,673	3,294						
	Average increase from fertilizers						233	835	1,202	949	805	

(1) 480 pounds nitrate in 1889. (2) 160 in 1889.

(3) Corrected weight. The weights reported for "straw" in the bulletin for 1890, page 52, include total produce.

The crop of 1889 was grown on clover sod, thoroughly underdrained. The yield of the unfertilized plots averaged almost 43 bushels per acre, which is nearly three times the average yield of the state for that season (14.6 bus.) Our method of calculation shows an apparent increase of yield on plots 2 and 3, dressed with superphosphate and potash singly; but the fact that the actual yields of these plots were both smaller than plot 1, and the close agreement in subsequent years in the yields of plots 1, 4 and 7, give ground for the suspicion that the apparent increase on plots 2 and 3 this season is due wholly to an abnormally low yield in plot 4, and not to any effect of the fertilizers. This suspicion is strengthened by the low yields of plots 6, 8 and 9, on which superphosphate and potash were used in combination with each other or with nitrate of soda.

On the plots receiving a complete fertilizer, that is, one containing nitrogen, phosphoric acid and potash, all three, there seems to have been a general increase of crop. The low yields on plots 17 and 18 may possibly have been due to the slower action of the rock and slag phosphate than of the superphosphate, a surmise which is supported by the marked superiority in yield of these plots in subsequent years. This may possibly explain the small increase in plot 21, also.

Considering the results of this season's experiments as a whole, it seems that the clover sod has furnished a very large supply of available plant food in just the condition and proportion required to most effectually meet the needs of the wheat plant, and that no increase of crop beyond what the clover sod was able to produce has been obtained until a complete fertilizer was added.

In the crop of 1890 the average yield of the unfertilized plots was 31.1 bushels, the average yield of the state for that year being 11.4 bushels. This season there was apparently an increase from every application of fertilizer, the increase being generally larger where a complete fertilizer was used, but it would seem that the combination of phosphoric acid and nitrogen has been as effective in grain production as the complete fertilizer. It should be noted, however, that the straw yield apparently rises when potash is added to the combination of nitrogen and phosphoric acid.

In the crop of 1891 the average yield of the unfertilized plots was 31.4 bushels, a slight increase over the yield of 1890, although this was the third season of continuous cropping. The average yield of the state that year was estimated by the Secretary of the State Board of Agriculture in October, at 17.5 bushels, a yield surpassed only once since 1850, namely, in 1879, when it was 17 8 bushels.

The experiments of 1891 present the remarkable phenomenon of a uniform decrease in yield of grain wherever bone-black superphosphate was used. The plots receiving rock and slag phosphates show no decrease, and little or no increase. Nitrate of soda seems to have had no effect on the grain yield, whether used alone or in combination, and if potash had any effect it was unfavorable. In the case of the straw yield,

however, the very opposite effect is observed; wherever phosphoric acid was used the yield of straw was largely increased; when nitrogen was added to the phosphoric acid a still greater increase of straw was obtained, and when, in this combination, the phosphoric acid was used in the form of bone black supherphosphate the increase of straw reached a ton to the acre—straw enough to have borne nearly twenty bushels of wheat, had it carried grain in the same proportion as the straw of the unfertilized plots.

In the crop of 1892 the average yield of grain on the unfertilized plots fell to 26.5 bushels, the yield for the state at large being about half this quantity. The yield of plot 2, taken alone, would indicate a considerable increase from the use of bone-black superphosphate this year; but this indication is not supported by the yields of the other plots upon which the same superphosphate was used, hence we must conclude that the increase indicated on plot 2 is accidental. Nitrogen seems to have had little or no effect this season, and although an increase is indicated in every case where a complete fertilizer was used it is extremely small. In the case of the straw yields, a decided increase is shown wherever phosphoric acid was used, and this increase was greatest where the phosphoric acid was used in the form of bone-black superphosphate.

Considering now the four years' work as a whole, we find that no chemical fertilizer or combination of such fertilizers has, in a single instance, produced sufficient increase of grain to pay the cost of the fertilizer, except, possibly, in the case of plot 2 in 1892, a case which, as has already been stated, was probably accidential. What is much more remarkable is the fact that the fertilizers have apparently had, in many cases, a smaller effect in the fourth season of continuous cropping, the fertilizers being applied every year, than they had on the clover sod. This is shown in the case of the plot dressed with barn-yard manure, and in those of the four plots, 11, 12, 14 and 15, dressed with a complete fertilizer containing bone-black superphosphate. The average increase from these plots is collected in tables IV and V in order to give a more comprehensive view:

TABLE IV—INCREASE OF GRAIN FROM COMPLETE FERTILIZER CONTAINING BONE-BLACK SUPERPHOSPHATE.

Plot No	Fertilizer.	Increase or Decrease (—) per acre.				
		1889.	1890.	1891.	1892.	Average.
		Bushels	Bushels	Bushels.	Bushels.	Bushels.
11	Chemical, complete...	5.4	5 3	—2.5	1 4	2.5
12	" "	5.2	5 0	—1.7	2 0	2.6
14	" "	4 9	4.2	—2 5	2.1	2.4
15	" "	7.1	2 2	—1.2	3 0	2.7
20	Barn-yard manure..... ...	5.3	5 2	—2 7	1 1	2.2
	Average increase.....	5.6	4.4	—2.1	1 9	2.5

TABLE V—INCREASE OF STRAW FROM COMPLETE FERTILIZER CONTAINING BONE-BLACK SUPERPHOSPHATE.

Plot No.	Fertilizers.	Increase per acre				
		1889.	1890.	1891	1892	Average.
		Pounds	Pounds	Pounds.	Pounds.	Pounds.
11	Chemical, complete ...	754	1,250	2,017	1,552	1,409
12	" " ...	730	1,551	2,298	1,543	1,530
14	"	311	1,4[illegible]	2,2[illegible]9	1,447	1,375
15	" " ...	3[illegible]6	4[illegible]5	1,2[illegible]0	1,1[illegible]8	800
20	Barnyard manure .	770	9[illegible]1	1,[illegible]5	7[illegible]7	1,048
	Average increase ...	58[illegible]	1,141	1,912	1,293	1,232

It would seem from tables IV and V that, by use of barnyard manure, or of a complete fertilizer containing bone-black superphosphate, the normal yield of 43 bushels per acre given by the clover sod in 1889 was increased by a larger quantity than the yield of 26½ bushels given by the same land in the fourth year of successive cropping, the same dressing of fertilizers or manure being repeated each year.

Whether the increase of crop indicated when a complete fertilizer was used on the clover sod was actually due to the fertilizer, or was only the result of irregularities in the soil, it is impossible to tell. This point is worthy of farther investigation. There seems no reason to doubt, however, that the increase indicated in 1890 was actually due to the fertilizers, and this, it will be seen, was more than double that obtained two years later from the same plots and in a much smaller average yield.

THE LODGING OF WHEAT.

The variety of wheat grown in these tests—Velvet Chaff (Penquite's)—is among those least subject to lodging of all the varieties yet tested by this Station, but it will go down sometimes. In 1889 the entire plot under experiment stood perfectly; in each of the three following years more or less of the grain went down, the relative lodging being shown in table VI:

TABLE VI—FERTILIZERS ON WHEAT THREE YEARS IN SUCCESSION.

Percentage of STRAW *lodged*

Plot No.	Fertilizers.	1890.	1891.	1892.
1	None			
2	Superphosphate		5	
3	Muriate of potash			
4	None			
5	Nitrate of soda		20	
6	Nitrate and superphosphate		80	50
7	None			
8	Superphosphate and potash		5	40
9	Nitrate and potash		5	50
10	None			
11	Superphosphate, potash and nitrate 160		100	100
12	Superphosphate, potash and nitrate 320		100	100
13	None			
14	Superphosphate, potash and nitrate 480	80	100	100
15	Superphosphate, potash and ammonia			20
16	None			
17	Rock phosphate, potash and n trate		5	5
18	Slag phosphate, potash and nitrate		5	5
19	None			
20	Barnyard manure		60	100
21	Linseed oil-meal		20	50
22	None			

The increasing tendency to lodge manifested in 1891 and 1892 is probably not altogether due to the fertilizers, as the wheat grown on unfertilized land has manifested this tendency to a greater degree during these two seasons than during the two preceding; but it is plainly partly due to the fertilizers, and whether a smaller application would produce a better proportionate result is a question which cannot be satisfactorily answered until the Station has more land at its disposal for this work. The results obtained on plots 17 and 18 suggest the possibility of overcoming this tendency by the use of other fertilizing materials; but this point cannot yet be fully investigated, for the reason already given.

In table VII is given the weight of grain per measured bushel for the last three seasons, and the pounds of straw required to carry a bushel of grain for each plot for each of the four seasons:

TABLE VII—FERTILIZERS ON WHEAT, FOUR YEARS IN SUCCESSION.

Weight of GRAIN *per measured bushel, and pounds of straw to one bushel of grain.*

Plot No.	Fertilizers.	Weight per bushel.				Straw to bushel.					Plot No.
		1890.	1891.	1892.	Average.	1889.	1890.	1891.	1892.	Average.	
1	None	64¾	62½	59½	62¼	80	113	140	115	112	1
2	Superphosphate (dissolved bone-black)	64½	61	61	62¼	82	109	170	137	124	2
3	Potash (muriate)	65	61½	60½	62¼	80	95	124	113	103	3
4	None	64½	61	60½	62	90	103	124	98	104	4
5	Nitrate of soda	64	62	59½	61¾	89	108	118	97	103	5
6	Nitrate and superphosphate	64	61¼	59½	61½	86	113	171	132	125	6
7	None	64⅓	62¾	59¼	62¼	85	101	120	100	101	7
8	Superphosphate and potash	64¼	62½	61	62½	80	114	150	120	116	8
9	Nitrate and potash	64¼	61⅓	60	62	99	105	132	103	110	9
10	None	64	61¾	61	62¼	80	113	114	100	102	10
11	Superphosphate, potash and nitrate, 160	64¼	60	58¾	61	86	128	197	151	140	11
12	Superphosphate, potash and nitrate, 320	64⅓	60	58	61	86	135	192	149	140	12
13	None	63¾	61¾	60¾	62	80	104	118	106	102	13
14	Superphosphate, potash and nirate, 480	62¾	60½	56¾	60	88	131	202	145	140	14
15	Superphosphate, potash and ammonia	63⅖	61¾	60½	62	83	110	156	127	119	15
16	None	63¾	62¼	59¾	62	96	102	104	97	100	16
17	Rock phosphate, potash and nitrate	63¾	62⅖	60	62	86	112	146	119	116	17
18	Slag phosphate, potash and nitrate	64	62½	60	62¼	90	116	151	122	120	18
19	None	64	62¾	59⅔	62	88	95	107	97	97	19
20	Barnyard manure	63¾	60¾	57½	60¾	90	111	176	122	125	20
21	Linseed oil-meal	63	.....	58	60½	93	111	134	103	110	21
22	None	63¾	.....	59¾	62	72	101	102	90	91	22
	Average of unfertilized plots	64⅛	62¼	60	62	84	104	116	100	101	

(1) 480 lbs nitrate in 1889.

(2) 160 lbs nitrate in 1889.

CO-OPERATIVE EXPERIMENTS WITH FERTILIZERS ON WHEAT.

At the time the experiment just described was begun, a similar test was started in Columbiana county, on a thin soil, derived from slaty rocks and partially drained by the cleavage of the underlying rocks.

The fertilizers were applied to plots 1 to 11, inclusive, in the same quantities as to the similarly numbered plots in the test at the Station farm, and barnyard manure was used on plot 12 in this test in duplication of plot 20 at the Station. As at the Station, nitrate of soda was used in all cases at the rate of 480 pounds per acre on the crop of 1891, but only 160 pounds per acre since. Muriate of potash was used at the rate of 160 pounds per acre in 1889 and 1890, and 80 pounds per acre in 1891. Plot 14 received common salt in 1889 instead of land plaster. Both salt and plaster have been used at the rate of 400 pounds per acre. In tables VIII and IX are given the results of this experiment for 1889, 1890 and 1891, those for 1891 not having previously been published. In 1892 the experiment was a failure, owing to the total failure of the crop. Velvet Chaff wheat was grown in this test in 1889 and 1890, and Fultz in 1891.

TABLE VIII—FERTILIZERS ON WHEAT IN COLUMBIANA COUNTY, THREE YEARS IN SUCCESSION.

Yield and increase of GRAIN *in bushels per acre.*

Plot No.	Fertilizers.	Yield per acre.				Increase or decrease (—) per acre.				Plot No.
		1889.	1890.	1891.	Average.	1889.	1890.	1891.	Average.	
1	None	9.3	13.8	11.8	11.6					1
2	Superphosphate (dissolved bone-black)	13.3	21.0	16.2	16.8	3.7	5.1	2.8	3.8	2
3	Potash (muriate)	11.0	18.7	17.0	15.6	1.2	0.6	1.9	1.3	3
4	None	10.1	20.2	16.8	15.7					4
5	Nitrate of soda	13.3	21.5	19.8	18.2	3.4	2.3	1.5	2.4	5
6	Nitrate and superphosphate	15.0	22.2	22.1	19.8	5.3	4.0	2.4	3.9	6
7	None	9.5	17.2	21.2	16.0					7
8	Superphosphate and potash	9.3	15.8	17.5	14.2	1.1	—0.6	—1.8	—0.5	8
9	Nitrate and potash	10.5	19.0	18.8	16.1	3.4	3.4	1.3	2.7	9
10	None	6.0	14.8	15.7	12.2					10
11	Superphosphate, potash and nitrate	10.6	18.3	21.3	16.7	5.9	5.0	5.4	5.4	11
12	Barnyard manure	4.1	17.2	16.8	12.7	0.8	5.3	0.7	2.3	12
13	None	2.0	10.3	16.3	9.5					13
14	Land plaster	1.5	11.5	13.0	8.7	—0.5	1.2	—3.3	—0.8	14
	Average of unfertilized plots	7.4	15.3	16.4	13.0					

TABLE IX—FERTILIZERS ON WHEAT IN COLUMBIANA COUNTY, THREE YEARS IN SUCCESSION.

Yield and increase of STRAW *in pounds per acre.*

Plot No.	Fertilizers.	Yield per acre.				Increase or decrease (—) per acre.				Plot No.
		1889.	1890.	1891.	Average.	1889.	1890.	1891.	Average.	
1	None	1,475	2,240	1,590	1,768					1
2	Superphosphate (dissolve bone-black)	1,740	3,320	1,730	2,263	207	895	73	392	2
3	Potash (muriate)	1,540	2,920	1,770	2,077	—52	307	47	101	3
4	None	1,650	2,800	1,790	2,080					4
5	Nitrate of soda	2,140	3,940	2,370	2,817	523	1,247	473	748	5
6	Nitrate and superphosphate	2,160	4,080	2,500	2,913	577	1,493	497	855	6
7	None	1,550	2,480	2,110	2,047					7
8	Superphosphate and potash	1,300	2,520	1,790	1,870	—127	213	—237	—50	8
9	Nitrate and potash	1,665	3,300	2,210	2,392	362	1,167	267	598	9
10	None	1,180	1,960	1,860	1,667					10
11	Superphosphate, potash and nitrate	1,560	3,000	2,360	2,307	580	1,193	587	787	11
12	Barnyard manure	945	2,300	2,060	1,768	165	647	373	395	12
13	None	580	1,500	1,600	1,227					13
14	Land plaster	495	1,480	1,720	1,232	—95	—20	120	5	14
	Average of unfertilized plots	1,287	2,196	1,790	1,758					

The tables show that although the average yield of this land is only about half as great as that on which the experiments at the Station are conducted, yet the increase from fertilizers has been practically no greater in Columbiana than in Franklin county, except that in 1891 the superphosphate seems to have produced a slight gain in Columbiana, instead of a loss, as in Franklin.

FERTILIZERS ON CROPS GROWN IN ROTATION.

Parallel with the experiments in continuous cropping an experiment has been conducted on the Columbus farm in which wheat is grown in rotation with other crops. In this experiment five blocks of land, each block containing seven plots of one-twentieth acre each, are cultivated in wheat, clover, timothy, corn and oats, the cropping being so managed that each crop is represented each year.

Following is the plan of fertilizing each block:

Plot 1. Unfertilized.

Plot 2. Superphosphate, 300 pounds per acre; muriate of potash, 80 pounds per acre,* on corn only.

Plot 3. Superphosphate, 300 pounds per acre; muriate of potash, 80 pounds per acre,* on wheat only.

Plot 4. Unfertilized.

Plot 5. Superphosphate, 300 pounds per acre; muriate of potash, 80 pounds per acre;* nitrate of soda, 160 pounds per acre, on wheat only.

Plot 6. Barnyarnd manure, 8 tons per acre, on wheat only.

Plot 7. Unfertilized.

*160 pounds, previous to 1892

Table X shows the yields for 1892 of the crops of wheat, clover, timothy and oats grown in this rotation; the corn crop has not yet come under the rotation.

TABLE X—FERTILIZERS ON CROPS GROWN IN ROTATION, 1892.

Yield and increase per acre.

Wheat—Block C.					Clover—Block A.			Oats—Block D.			Value of increase.‡
Grain.			Straw.					Grain.			
Plot No.	Yield.	Increase.	Yield.	Increase.	Plot No.	Yield.	Increase.	Plot No.	Yield.	Increase.	
	Bush.	*Bush.*	*Pounds*	*Pounds*		*Pounds.*	*Pounds*		*Bush*	*Bush*	*Dols*
1	34.2	.....	3,530	.....	25	†.....	.....	8	29.2	.....	.....
2	32 4	0 1	3,040	—220	26	5,000	.....	9	37.3	6 7	2 08
3	35.7	5.4	3,440	477	27	5,000	40	10	33 0	1 1	4.82
4	28.4	.....	2,680	.....	28	4,920	.....	11	33.3	.....	.....
5	35.6	6 7	3,550	963	29	5,200	360	12	35 8	3 1	8 47
6	28.4	*—0.9	2,980	487	30	5,120	360	13	27.7	—4.3	.23
7	29.7	.....	2,520	.....	31	4,680	.....	14	31.4	.....	.....

*Decrease †The clover on part of this plot was destroyed by accident, hence it is not included in the test of this year. ‡The value of increase is computed on the basis of the following prices: Wheat, 70 cents per bushel; straw, $2.00 per ton; hay, $10.00 per ton, oats, 33 cents per bushel.

It will be observed that the apparent increase of grain from the superphosphate is greater in this rotated wheat than in that grown continuously, and that the fertilizers have apparently expended the greater part of their strength on the crops to which they were applied, leaving but little surplus for the following crops.

We cannot say that the case might not be different were the phosphoric acid applied in a form not so quickly available as superphosphate, such as bone meal or basic slag.

The average yield of the unfertilized plots in this rotation is 30.8 bushels per acre; that of the unfertilized plots where wheat is grown continuously is 26.5 bushels for the same season, 1892,—a difference almost as great as any produced by fertilizers. Moreover, the wheat grown in rotation stood almost perfectly, the only patch of lodged grain being a small part of plot 1.

In table XI is given the average yield of grain and straw and the average number of pounds of straw required to produce a bushel of grain under continuous as compared with rotative cropping for the two seasons, 1891 and 1892; the treatment being alike in other respects:

TABLE XI—CONTINUOUS, COMPARED WITH ROTATIVE CROPPING OF WHEAT.

Average results for two seasons.

Fertilizers.	Yield per acre.				Straw to one bushel.	
	Grain.		Straw.			
	Continuous.	Rotative.	Continuous.	Rotative.	Continuous.	Rotative.
	Bushels	*Bushels*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
None	29.0	34.0	3,172	3,655	109	107
Superphosphate and potash	30 3	35.9	4,122	4,635	136	129
Superphosphate, potash & nitrate	28.9	35 9	5,032	4,835	174	135
Barnyard manure	26 3	33.2	3,960	3,750	150	113

This table shows that the rotation employed in this experiment has added from five to seven bushels to the crop of wheat, the treatment being similar in other respects, and it shows that, while the actual produce of straw, in the absence of nitrogenous fertilizers, has been greater under rotative than under continuous cropping, yet it has invariably required less straw to carry a bushel of grain under rotation, the treatment being otherwise the same.

FERTILZERS ON OATS GROWN CONTINUOUSLY ON THE SAME LAND.

Adjoining the section devoted to the continuous culture of wheat is another of the same size on which oats have been grown continuously for four seasons.

The soil of this section differs from that on which wheat is grown in being underlaid with gravel, which gives partial drainage. This drainage has been supplemented, however, by tiles, laid on the same plan as under the wheat plots.

The plan of fertilizing is the same for the oats as for the wheat, except that in 1892 dried blood, at the rate of 160 pounds per acre, was substituted for the large dressing of nitrate of soda on plot 14, the experience of the three preceding seasons having shown that such excessive applications invariably cause the oats to lodge and thus reduce the yield.

Tables XII and XIII give the yield and increase of grain and straw for each of the four seasons, 1889 to 1892, and the average yield and increase for the entire period.

TABLE XII—FERTILIZERS ON OATS, FOUR YEARS IN SUCCESSION.

Yield and increase of GRAIN *in bushels of 32 pounds.*

Plot No.	Fertilizers.	Yield per acre.					Increase or decrease (—) per acre.					Plot No.
		1889.	1890.	1891.	1892.	Average.	1889.	1890.	1891.	1892.	Average.	
1	None	44.2	16.0									1
2	Superphosphate (dissolved bone black)	46.9	19.4	46.6	29.4	35.6	1.4	3.4	6 4	0.6	2.3	2
3	Potash (muriate)	59.5	19.7	45.9	32 5	39.4	12.6	3.7	5.7	3.7	6.1	3
4	None	48.2	16.0	40.2	28.8	33.3						4
5	Nitrate of soda	47.2	21.1	45.6	32.7	36.6	0.1	3.9	5.3	5.4	3 6	5
6	Nitrate and superphosphate	48.4	22.3	51.2	32.2	38.5	2.3	3.8	10.7	6.4	5.8	6
7	None	45.0	19.7	40.6	24.3	32.4						7
8	Superphosphate and potash	45.0	21.6	46.6	32.2	36.3	—0.8	2 3	4.3	4.5	2.5	8
9	Nitrate and potash	48.4	23.7	46.6	40.3	39.7	1.8	4.9	2.7	9.3	4.6	9
10	None	47.5	18.4	45.6	34.4	36.5						10
11	Superphosphate, potash and nitrate, 160	52 9	24.7	50.9	40.9	42.3	5.6	7.4	6.0	3.6	5.6	11
12	Superphosphate, potash and nitrate, 320	47 8	25.3	52.3	43.1	42.1	0.8	9.0	8.2	3.0	5.2	12
13	None	46.8	15.2	43.4	43.0	37.1						13
14	Superphosphate, potash and nitrate, 480	45.0	20.8	48.4	43.3	39.4	1.6	4.3	3.9	2.1	3.0	14
15	Superphosphate, potash and ammonia	51.8	23.9	49.4	40.1	41.3	11.9	6.0	3.9	0.8	5.6	15
16	None	36.5	19.2	46.6	37.5	34.9						16
17	Rock phosphate, potash and nitrate	47.3	21.6	49.7	41.1	39.9	10.3	4.0	3.7	4.0	5.5	17
18	Slag phosphate, potash, and nitrate	45.7	22.8	51.6	43.6	40 9	8.4	6.7	6.3	6.8	7.0	18
19	None	37.9	14.5	44.7	36.4	33.4						19
20	Barnyard manure	42.8	19.1	50.3	36.9	37.3	2.2	3.3	5.6	0.5	2.9	20
21	Linseed-oil meal	50.6	14.8	46.7	25.8	34.5	7.2	—2.3	2.0	—10.6	1.1	21
22	None	46.1	18.4									22
	Average of unfertilized plots	44.0	17.2	42.8	34 1	34.6						
	Average increase from fertilizers						4.7	4.5	5.3	2.9	4.3	

*Dried blood 160 pounds, instead of nitrate in 1892.

TABLE XIII—FERTILIZERS ON OATS, FOUR YEARS IN SUCCESSION.

Yield and increase of STRAW *in pounds per acre.*

Plot No.	Fertilizers.	Yield.					Increase or decrease (—).					Plot No.
		1889.	1890.	1891.	1892.	Average	1889.	1890.	1891.	1892.	Average	
1	None	3,180	1,900									1
2	Superphosphate	3,520	2,370	3,310	2,960	3,040	133	343	845	180	375	2
3	Muriate potash	4,220	2,270	2,680	3,100	3,082	627	317	215	380	385	3
4	None	3,800	1,980	2,465	2,780	2,756						4
5	Nitrate soda	3,980	2,680	2,540	3,155	3,089	233	653	100	478	441	5
6	Superphosphate and nitrate	4,068	2,900	2,160	3,020	3,037	375	827	—260	445	346	6
7	None	3,640	2,120	2,400	2,472	2,658						7
8	Superphosphate and potash	3,660	2,580	2,910	3,170	3,080	—87	300	430	539	295	8
9	Potash and nitrate	4,040	3,070	2,810	2,960	3,220	197	630	250	169	311	9
10	None	4,960	2,600	2,640	2,950	3,037						10
11	Superphosphate, potash and nitrate, 160	4,400	3,210	2,620	2,940	3,292	487	587	5	—68	253	11
12	Superphosphate, potash and nitrate, 320	4,300	3,320	2,875	3,020	3,379	433	673	290	—47	337	12
13	None	3,820	2,670	2,560	3,125	3,044						13
14	Superphosphate, potash and nitrate, 480*	3,880	2,930	2,550	3,665	3,256	267	450	57	732	376	14
15	Superphosphate, potash and ammonia	3,060	3,270	2,670	2,985	3,241	653	980	243	223	525	15
16	None	3,200	2,100	2,360	2,550	2,552						16
17	Rock phosphate, potash and nitrate	3,800	2,910	2,110	3,435	3,064	647	860	—120	640	507	17
18	Slag phosphat , potash and nitrate	3,500	3,120	2,200	3,205	3,006	363	1,120	100	165	444	18
19	None	3,060	1,950	1,970	3,285	2,566						19
20	Barnyard manure	3,140	2,650	2,540	3,420	2,937	—167	450	570	143	249	20
21	Linseed oil meal	4,100	2,470	2,215	3,675	3,115	547	20	245	407	305	21
22	None	3,800	2,700		3,260							22
	Average of unfertilized p'ots	3,557	2,252	2,400	2,917	2,768						
	Average increase from fertilizers						338	586	212	313	362	

*Dried blood, 160 lbs , instead of nitrate in 1892.

It appears from this table that in the case of oats there has been a constant increase of grain following the use of fertilizers, the only case where there was any marked falling off in the yield of grain being on the plot where oil meal was used, and this may be explained by the early lodging of the oats on this plot.

It appears that each of the three fertilizing materials used—superphosphate, muriate of potash and nitrate of soda—has in nearly every case produced an increase of crop. It would seem that potash is having a more favorable effect upon the oats than upon the wheat, and it seems that the combination of nitrogen with either phosphoric acid or potash has on the average produced a larger increase than that following the separate use of either of the three materials, but no single fertilizer, nor no combination of fertilizers, has produced an increase in the average crop sufficient to pay the cost of the fertilizer.

In the case of the oats straw it will be observed that, while there is a general increase of straw following the use of the fertilizers, this increase is usually much smaller than in the case of wheat.

FERTILIZERS ON CORN GROWN CONTINUOUSLY ON THE SAME LAND.

The section devoted to fertilizer experiments with corn grown continuously on the same land at the Columbus farm lies immediately north of that devoted to similiar experiments with oats, and the plots of the same number are continuous through both sections, being crossed by a narrow roadway which separates the sections. The soil of both sections lies over gravel, the gravel being a little nearer the surface (within three to five feet) under the corn than under the oats. As there are areas where the gravel drainage is not perfect it has been supplemented by tile drains, laid 36 feet apart.

Five successive crops of corn have been grown on this land, and the results are given in tables XIV and XV.

TABLE XIV—FERTILIZERS ON CORN, FIVE YEARS IN SUCCESSION.

Yield and increase of GRAIN *in bushels of 70 pounds of ears.*

Plot No.	Fertilizer.	Yield per acre.						Increase or decrease (—) per acre.						Plot No.
		1888.	1889.	1890.	1891.	1892.	Aver'ge.	1888.	1889.	1890.	1891.	1892.	Av'ge.	
1	None	86.0	64.6	51.3	56.4	66.3	64.9	.....	.....	.....	.....	.....	.....	1
2	Superphosphate (disolved bone black)	83.0	65 0	49.4	61.1	61.4	64.0	—5.7	—0.8	—2.0	4.1	—3.9	—1.6	2
3	Potash (muriate)	89.4	60.0	50.3	61.7	65.7	65.4	—2.1	—7.1	—1.2	4.0	1.4	—1.0	3
4	None	94.2	68.3	51.6	58.3	63.3	67.1	.....	.....	.....	.....	.....	.....	4
5	Nitrate of soda	91.4	67.7	50.4	68.1	74.9	70.5	—2.4	2.4	1.3	9.8	11.1	4.4	5
6	Nitrate and superphosphate	96.8	68.9	50.3	69.7	73.6	71.9	3.4	6.6	3.7	11.5	9.3	6.9	6
7	None	93.0	59.3	44.1	58.2	64.7	63.9	.....	.....	.....	.....	.....	.....	7
8	Superphosphate and potash	89.5	63.7	48.4	54.2	74.0	66.0	—3.2	3.8	3.2	—4.4	8.9	1.7	8
9	Nitrate and potash	93.1	67.6	53.9	68.0	76.4	71.8	0.7	7.1	7.6	9.0	10.9	7.1	9
10	None	92.1	61.1	47.4	59.4	66.0	65.2	.....	.....	.....	.....	.....	.....	10
11	Superphosphate,potash and nitrate,160	85.7	71.1	50.5	69.5	76.0	70.6	—5.9	7.8	2.9	10.0	9.3	4.8	11
12	Superphosphate,potash and nitrate 320	93.7	63.9	54.1	71.6	77.4	72.1	2.7	—1.6	6.2	12.0	9.9	5.8	12
13	None	90.5	67.7	48.1	59.7	68.3	66.9	.....	.....	.....	.....	.....	.....	13
14	Superphosphate,potash and nitrate,480	89.2	61.4	50.3	68.2	79.9	69.8	—0.3	—2.6	3.7	11.6	13.9	5.2	14
15	Superphosphate,potash and ammonia	88.0	57.4	45.7	65.6	69.6	65.3	—0.4	—3.0	0.6	12.1	5.8	3.1	15
16	None	87.4	56.7	43.6	50.4	61.4	59.9	.....	.....	.....	.....	.....	.....	16
17	Rock phosphate, potash and nitrate	89.2	57.3	47.8	67.1	76.0	67.5	4.7	1.0	5.4	16.3	13 4	8.2	17
18	Slag phosphate, potash and nitrate	89.4	61.0	47.5	63.2	75.0	67.2	7.9	5.2	6.5	11.5	11.3	8.5	18
19	None	78.6	55.4	39.9	52.3	64.9	58.2	.....	.....	.....	.....	.....	.....	19
20	Barnyard manure	93.9	66.4	45.1	62.7	70.3	67.7	8.2	9.0	2.9	6.7	4.2	6.2	20
21	Linseed oil meal	105.2	72.6	46.2	70.2	73.7	73.6	12.3	13.3	1.6	10.5	6.4	8.8	21
22	None	100.0	61.3	47.0	63.4	68.6	68.1	.....	.....	.....	.....	.....	.....	22
	Average of unfertilized plots	90.2	61.8	46.6	57.3	65.4	64.3	.....	.....	.....	.....	.....	.....	
	Average increase from fertilizers	.....	.....	.....	.....	.....	.....	1.4	2.9	3.0	8.9	8.0	4.9	

TABLE XV—FERTILIZERS ON CORN, FIVE YEARS IN SUCCESSION.

Yield and increase of STALKS* *in pounds per acre.*

Plot No.	Fertilizers.	Yield per acre.						Increase or decrease (—) per acre.						Plot No.
		1888.	1889.	1890.	1891.	1892.	Aver'ge.	1888.	1889.	1890.	1891.	1892.	Av'ge.	
1	None	7,600	3,472	2,436	3,640	3,420	4,114							1
2	Superphosphate (dissolved bone black)	6,195	3,276	2,514	3,520	3,390	3,779	—937	—227	56	—73	—247	—286	2
3	Potash (muriate)	7,255	3,390	3,246	3,800	4,500	4,438	592	—143	765	253	647	423	3
4	None	6,195	3,564	2,503	3,500	4,070	3,966							4
5	Nitrate of soda	8,256	3,788	2,932	4,260	4,950	4,837	1,896	265	497	737	870	841	5
6	Nitrate and superphosphate	7,171	3,604	2,790	4,350	5,300	4,643	647	122	302	804	1,210	614	6
7	None	6,689	3,441	2,480	3,570	4,100	4,056							7
8	Superphosphate and potash	6,661	3,762	2,780	3,930	4,720	4,371	—222	210	367	413	703	295	8
9	Nitrate and potash	7,805	4,101	3,040	4,020	5,210	4,835	728	438	604	557	1,277	738	9
10	None	7,271	3,774	2,280	3,410	3,850	4,117							10
11	Superphos., potash and nitrate, 160	6,959	3,488	2,966	4,190	4,980	4,507	—308	—253	624	693	1,053	362	11
12	Superphos., potash and nitrate, 320	6,456	4,028	2,857	4,200	5,350	4,578	—808	320	454	617	1,447	406	12
13	None	7,260	3,675	2,465	3,670	3,930	4,200							13
14	Superphos., potash and nitrate, 480	7,087	3,660	3,141	4,040	5,400	4,666	378	296	714	600	1,670	732	14
15	Superphosphate, potash and ammonia	7,475	3,270	3,276	**	4,850	4,718	1,318	216	886	.....	1,320	935	15
16	None	5,606	2,743	2,352	2,980	3,380	3,402							16
17	Rock phosphate, potash and nitrate	7,235	3,780	2,781	3,900	4,660	4,471	1,318	962	411	924	1,273	978	17
18	Slag phosphate, potash and nitrate	6,670	3,392	2,903	3,720	4,700	4,277	443	500	516	747	1,267	695	18
19	None	6,538	2,968	2,405	2,970	3,500	3,676							19
20	Barnyard manure	5,866	3,519	2,802	3,880	3,930	4,000	—693	506	230	927	413	277	20
21	Linseed oil meal	7,573	3,830	3,304	3,840	4,950	4,700	993	772	565	903	1,417	931	21
22	None	6,601	3,103	2,906	2,920	3,550	3,816							22
	Average of unfertilized plots	6,720	3,342	2,478	3,333	3,720	3,919							
	Average increase from fertilizers							382	285	541	579	929		

*Stalks and leaves the corn being cut about four inches above the ground
**Stalks burned by trespassers.

Considering tables XIV and XV, it appears that there has been a loss of crop in four seasons out of five on the plot dressed with superphosphate alone, and in three of the five seasons on the plot treated with potash alone, while the plot on which these two substances have been used together shows practically no gain in the average of the five seasons. It seems quite clear that, in this series of experiments, superphosphate and potash have added nothing to the crop of grain, and but little to the growth of stalks, until combined with nitrogen.

The plot dressed with nitrate of soda shows a small gain in every season except the first, and that dressed with nitrate and superphosphate shows an increase every year, the average gain for the five seasons amounting nearly to seven bushels, a gain which is not increased by the addition of potash. Practically the same increase is shown by the combination of nitrate and potash, however, without any superphosphate, hence we must conclude that nitrogen is the controlling factor in producing an increase of the corn crop on this soil.

It will be observed that in the case of the corn the fertilizers seem to be having a greater effect during the later years of the experiment, and this appears to be due, not to the exhaustion of the unfertilized plots—for their average yield in the fifth season of the test was greater than for any other season except the first, and for the fourth season it was but little behind that of the second—but to a gradual accumulation of available plant food in the fertilized plots. It is interesting to note that the yield of plot 14, receiving 880 pounds per acre of a complete fertilizer, 480 pounds of which was nitrate of soda, reached a total yield of almost eighty bushels of shelled corn per acre in 1892, although this is still ten bushels below the average yield of the unaided clover sod in 1888.

It will be observed that, even in those seasons when the effect of the fertilizers was most strongly marked, it has in most cases required a dollar's worth of fertilizer, or more, to produce a bushel of increase in the crop.

Of the various complete fertilizers used, the one containing Carolina rock as the source of phosphoric acid has produced the largest average increase of corn in proportion to cost of fertilizer.

FERTILIZERS ON CORN IN WAYNE COUNTY

It is designed to continue the study of soils and fertilizers at the new home of the Station in Wayne county, and it is hoped that the larger area of land at our disposal may enable us to investigate some points more in detail than has been possible hitherto. The use of fertilizers on crops grown in rotation will hereafter occupy a leading position in these investigations, although wheat, oats and corn will still be grown in continuous culture.

The work in the continuous culture of corn is the only branch of this investigation that it was possible to start in 1892. The land selected for this work was a piece of "run out" grass land, originally seeded with clover and timothy, but which had not been cultivated for several years, and the grass had been replaced by plantain and other weeds in many places. It is considered one of the poorest fields on the Station farm. Table XVI gives the plan of the experiment, with the results for 1892. The number following the name of each fertilizer indicates the number of pounds used per acre. It will be observed that, as a rule, the fertilizers are used in smaller quantities in this test than in those heretofore described, although certain plots are fertilized to the full amount for comparison.

TABLE XVI—FERTILIZERS ON CORN IN WAYNE COUNTY, 1892.

Yield and increase of GRAIN, *per acre, in bushels of 70 pounds ears.*

Plot No.	Fertilizers per Acre.	Yield.		Increase or decrease (—)	
		Grain	Stalks	Grain	Stalks
		Bush'ls	*Pounds*	*Bush'ls*	*Pounds*
1	None	49.1	2,100	.....	.....
2	Superphosphate, (dissolved bone black) 160	59.9	2,420	12.5	363
3	Potash, (muriate) 100	52.0	2,290	6.4	277
4	None	43.9	1,970	.....	.....
5	Nitrate of soda, 160	32.0	1,790	—9.6	—143
6	Nitrate, 160; superphosphate, 160	42.9	1,860	3.6	— 37
7	None	37.0	1,860	.....	.....
8	Superphosphate, 160; potash, 100	58.3	2,400	22.2	517
9	Nitrate, 160; potash, 100	42.4	2,080	7.2	137
10	None	34.3	1,930	.....	.....
11	Superphosphate, 160; potash, 100; nitrate, 160	51.9	2,420	14.7	440
12	Superphosphate, 160; potash, 100; nitrate, 320	56.9	2,620	16.9	590
13	None	42.9	2,080	.....	.....
14	Superphosphate, 160; potash, 100; nitrate, 480	49.6	2,390	8.8	360
15	Superphosphate, 320; potash, 100; nitrate, 160	55.4	2,400	16.9	420
16	None	36.4	1,930	.....	.....
17	Superphosphate, 160; potash, 50; nitrate, 160	54.0	2,370	14.2	390
18	Superphosphate, 160; potash, 10; nitrate, 80	59.1	2,440	16.0	410
19	None	46 4	2,080	.....	.....
20	Open yard manure, 5 tons	53.7	2,380	7.5	257
21	Covered yard manure, 5 tons	51.7	2,320	5.8	153
22	None	45.7	2,210	.....	.....
23	Superphosphate, 160; dried blood, 80	50.4	2,340	4.9	157
24	Superphosphate, 160; sulphate ammonia, 64	58.9	2,640	13.4	483
25	None	45.3	2,130	.....	.....
26	Carolina rock, 160; nitrate, 80	54.9	2,390	11.3	243
27	Basic slag, 140; nitrate, 80	46.3	2,070	2.7	—160
28	None	40.1	2,280	.....	.....
	Average of unfertilized plots	42.1	2,057	.....	.....
	Average increase from fertilizers	.....	.....	9.7	261

The results shown in table XVI indicate that phosphoric acid was the most important factor in a fertilizer for corn on this land in the season of 1892, for wherever superphosphate was used there is an increase of crop. Potash seems to have come next to superphosphate in increasing the yield, but nitrogen seems to have had little or no effect, whether carried to the crop in nitrate of soda, dried blood, or sulphate of ammonia. In-

deed, there is a considerable loss of crop indicated on plot 5, where nitrate of soda was used alone, but this may have been due to variations in the soil.

It was not possible to drain this land before beginning the experiment, and thus the irregularities due to unequal drainage have much to do with the irregularities in yield shown in the table, and this source of error was greatly aggravated by the excessive rainfall of May and June. At Wooster there were 21 rainy days in June, with a total precipitation of 15.58 inches, nearly evenly divided between the two months, whereas the average rainfall for ten years during these two months in this section of the State is but 8.46 inches, 4.37 inches for May and 4 09 inches for June. Under such conditions it is not surprising that so easily soluble a salt as nitrate of soda should have failed to produce any increase of crop. It was probably all washed out of reach of the corn roots at the very beginning of the season.

There were as many rainy days in May and June at Columbus as at Wooster but the total rainfall at the University farm was but 11.36 inches, while the ten-year average for that section of the State is 8.58 inches, so that the excess of precipitation amounted to 84 per cent. of the ten-year average at Wooster, and only 32 per cent. of that average at the Station farm at Columbus. This is probably one reason why the nitrate has made so much better showing in the experiment at Columbus than in that at Wooster.

CO-OPERATIVE EXPERIMENTS WITH FERTILIZERS ON CORN.

Co-orperative experiments with fertilizers on corn were made in 1892 by H. Y. Bentley in Columbiana county, Orlando Trotter in Washington county and B. H. Brown in Butler county, thus representing the extreme eastern, south-eastern and south-western parts of the State. Tables XVII to XXI give the plan and results of these experiments, the superphosphate being in all cases dissolved bone black and used at the rate of 320 pounds per acre, the muriate of potash being used at the rate of 80 pounds per acre in 1891 and '92, and 160 pounds per acre previous to 1891; the nitrate of soda at the rate of 160 pounds per acre, the barnyard manure at the rate of 8 tons per acre and the land plaster at the rate of 400 pounds per acre.

FARM TEST IN COLUMBIANA COUNTY.

Made by H Y Bentley.

This test has been repeated five years in succession on the same land and under the personal superintendence of the agriculturist of the Station. The land is high upland and underlaid with slaty rocks, which give partial drainage. Previous to 1888 it had been in pasture for several years, but the growth of grass (chiefly blue grass) had become quite uneven. Tables XVII and XVIII give the yield of grain and stalks for the five years:

TABLE XVII—FERTILIZERS ON CORN IN COLUMBIANA COUNTY.

Yield and increase of GRAIN *in bushels of 70 lbs. ears.*

Plot No.	Fertilizers.	Yield per acre.						Increase or decrease (—) per acre.						Plot No.
		1888.	1889.	1890.	1891.	1892.	Av'age.	1888.	1889.	1890.	1891.	1892.	Avg'r.	
1	None	35.5	52.9	20.4	21.3	16.0	29.2	.....	.....	.....	.....	.....	.....	1
2	Superphosphate	35.9	56.4	18.3	22.4	15.7	29.7	—2.3	1.8	—2.6	—2.0	—2.1	—1.5	2
3	Muriate of potash	39.4	56.2	19.5	27.3	18.1	32.1	—1.6	0	—1.8	—0.3	—1.8	—1.1	3
4	None	43.7	57 9	21.8	30.7	21.3	35.1	.....	.....	.....	.....	.....	.....	4
5	Nitrate of soda	70.8	58.5	30.2	38.2	26.5	44.8	18.1	—2.0	8.1	6.4	5.1	7.1	5
6	Nitrate and supurphosphate	90.0	62.2	30.1	37.5	23.8	48.7	28.4	—1.0	7.6	4.5	2.2	8.3	6
7	None	70.6	65,8	22.8	34.1	21.7	43.0	.....	.....	.....	.....	.....	.....	7
8	Superphosphate and potash	70 6	62 8	14.9	23.7	15 9	37.6	—0.1	—1.8	—8.1	—8.8	—6.1	—5.0	8
9	Nitrate and potash	90.4	67.0	31.7	39.0	26 5	50.9	20.0	3.6	8.4	8.1	4.1	8.8	9
10	None	70.2	62.2	23 5	29 3	22.7	41.6	.....	.....	.....	.....	.....	.....	10
11	Supurphos, potash and nitrate	74.8	66.1	24 9	31.9	24.3	44.4	7.7	5.4	1.4	2.7	2.5	4-0	11
12	Barnyard manure	61.8	73.8	30.6	28.5	22.7	43.5	—2-1	14.5	7.0	—0.7	2.4	4.2	12
13	None	60.8	57.8	23.6	29.1	19.1	38.1	.....	.....	.....	.....	.....	.....	13
14	Land plaster	60.0	59.9	20.5	23.5	15.4	35.9	—0.8	—2.1	—3.1	—5.6	—3.7	—2.2	14
	Average of unfertilized plots	56.2	59.3	22.5	26.9	20.2	37.4	.....	.....	.....	.....	.....	.....	
	Average increase from fertilizers	.....	.....	.....	.....	.....	.....	7.5	2.5	1.9	0.5	0.3	.....	

TABLE XVIII.—FERTILIZERS ON CORN IN COLUMBIANA COUNTY.

Yield and increase of STALKS, *in pounds, per acre.*

Plot No.	Fertilizers.	Yield per Acre.						Increase or Decrease (—) per Acre.						Plot No.
		1888	1889	1890	1891	1892	Aver'ge	1888	1889	1890	1891	1892	Av'ge	
1	None	4,520	2,797	1,914	2,170	2,285	2,738							1
2	Superphosphate	4,640	2,778	2,064	2,592	2,175	2,850	37	— 82	246	372	—139	87	2
3	Muriate of potash	5,050	3,001	2,125	2,934	2,282	3,078	363	77	402	663	— 60	289	3
4	None	4,770	2,987	1,627	2,321	2,371	2,815							4
5	Nitrate of soda	5,800	3,030	2,585	2,868	2,531	3,363	1,093	— 55	869	421	169	500	5
6	Nitrate and superphosphate	6,040	3,167	2,555	3,180	2,406	3,468	1,387	— 15	751	607	53	557	6
7	None	4,580	3,280	1,893	2,699	2,344	2,959							7
8	Superphosphate and potash	5,390	3,502	2,417	3,833	2,153	3,459	683	253	481	1,111	—209	464	8
9	Nitrate and potash	6,590	3,549	2,762	3,192	2 607	3,740	1,757	330	788	446	228	709	9
10	None	4,960	3,188	2,022	2,770	2,397	3,067							10
11	Superphophate potash and nitrate	6,500	3,346	2,285	3,188	2,598	3,571	1,350	210	461	393	186	520	11
12	Barnyard manure	5,140	3,757	2,595	3,828	2,474	3,559	—200	673	969	1,009	168	524	12
13	None	5,530	3,032	1,428	2,844	2,261	3,019							13
14	Land Plaster	5,810	3,028	1,520	2,480	2,080	2,984	280	— 4	92	—364	—181	— 35	14
	Average of unfertilized plots	4,872	3,057	1,777	2,561	2,332	2,920							

From these tables it appears that the use of superphosphate and potash, either singly or in combination with each other, but without nitrogen, has been followed by a decrease in yield of grain in every year except one, and in thirteen out of fifteen tests, although there has usually been an increase in yield of stalks. On the other hand, the use of nitrate of soda, either alone or combined with phosphoric acid or potash, one or both, has been followed by an increase in crop, both in grain and stalks, in every year but one, and in eighteen out of twenty tests. It appears, therefore, that, next to climatic conditions, nitrogen is the controlling factor in determining the yield of corn on this land. In this respect the results of this experiment are in close accord with those of the experiment at Columbus. In both experiments there has been an absolute loss on plots 2 and 3, while the small gain indicated in the average on plot 8 at Columbus amounts to nothing.

But the most surprising feature of these experiments is that while the effect of the fertilizers is evidently increasing at Columbus, it is as evidently decreasing in the Columbiana county test, although the average unfertilized yield at Columbus, since the second year of the test, has been twice or three times that in Columbiana county, and in 1892 the average increase over the unfertilized yield of sixty-five bushels per acre at Columbus was from two to four times as great as that on the similarly treated plots in Columbiana county, where the unfertilized yield was but twenty bushels per acre.

FARM TEST IN BUTLER COUNTY

Made by B H Brown

Mr. B. H. Brown, of Oxford, Butler county, has made this experiment in 1889, 1891 and 1892, but each time on fresh ground, the test of 1889 being made on wheat stubble, and those of 1891 and 1892 on timothy sod. The land was selected because of its lack of natural fertility, the soil being a heavy clay of drift origin. Tables XIX and XX give the results of the three crops:

TABLE XIX—FERTILIZERS ON CORN IN BUTLER COUNTY.

Yield and increase of GRAIN *in bushels of 70 pounds of ears.*

Plot No.	Fertilizers.	Yield per acre.				Increase per acre.				Plot No.
		1889.	1891.	1892.	Average.	1889.	1891.	1892.	Average.	
1	None	18.3	21.4	42.6	27.4	.....	.....	.....	.....	1
2	Superphosphate	35.9	39.6	42.9	39.5	15.1	15.4	0.3	10.3	2
3	Muriate of potash	41.7	32.3	62.1	45.4	18.3	5.3	19.5	14.4	3
4	None	25.9	29.9	42.6	32.8	.....	.....	.....	.....	4
5	Nitrate of soda	26.7	41.4	51.3	39.8	0.2	12.2	8.8	7.0	5
6	Nitrate and superphosphate	35.7	41.6	52.1	43.1	8.6	13.0	9.6	10.4	6
7	None	27.7	27.9	42.4	32.7	.....	.....	.....	.....	7
8	Superphosphate and potash	49.9	37.5	51.0	46.2	23.7	8.7	9.5	13.9	8
9	Nitrate and potash	37.9	47.7	51.4	45.7	13.1	18.1	10.3	13.8	9
10	None	23.3	30.5	40.9	31.6	.....	.....	.....	.....	10
11	Superphosphate, potash and nitrate	48.0	51.4	45.9	48.4	22.7	22.6	4.4	16.5	11
12	Barnyard manure	67.4	60.7	60.7	62.9	40.0	33.6	18.7	30.7	12
13	None	29.4	25.4	42 6	32.5	.....	.....	.....	.....	13
14	Land plaster	33.3	30.3	44.3	36.0	3.9	4.9	1.7	3.5	14
	Average of unfertilized plots	24.9	27 0	42.2	31.4	.....	.....	.....	.....	

TABLE XX—FERTILIZERS ON CORN IN BUTLER COUNTY.

Yield and increase of STALKS *per acre.*

Plot No.	Fertilizers.	Yield per acre.				Increase per acre.				Plot No.
		1889.	1891.	1892.	Average.	1889.	1891.	1892.	Average	
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	
1	None	1,320	1,652	2,710	1,894	.....	.....	.....	.....	1
2	Superphosphate	2,690	1,952	2,650	2,431	1,193	415	10	540	2
3	Muriate of potash	2,700	1,683	4,210	2,864	1,027	266	1,640	977	3
4	None	1,850	1,300	2,500	1,883	.....	.....	.....	.....	4
5	Nitrate of soda	2,000	1,447	2,800	2,082	67	—20	383	143	5
6	Nitrate and superphosphate	2,650	2,020	2,950	2,540	633	387	617	546	6
7	None	2,100	1,800	2,250	2,050	.....	.....	.....	.....	7
8	Superphosphate and potash	3,400	1,761	3,250	2,804	1,417	—93	950	758	8
9	Nitrate and potash	2,550	2,034	3,200	2,595	683	125	850	553	9
10	None	1,750	1,963	2,400	2,038	.....	.....	.....	.....	10
11	Superphosphate, potash and nitrate	3,370	2,173	3,990	2,844	1,530	205	557	764	11
12	Barnyard manure	4,680	2,835	3,980	3,832	2,750	863	1,513	1,709	12
13	None	2,020	1,977	2,500	2,166	.....	.....	.....	.....	13
14	Land plaster	2,380	1,869	2,700	2,316	360	—108	200	150	14
	Average of unfertilized plots	1,808	1,738	2,472	1,973	.....	.....	.....	.....	

Mr. Brown has succeeded in obtaining a much larger average increase from the use of potash and barnyard manure than has been obtained on the Station farms. The average increase on plots 2 and 3, if it can be maintained, will pay the cost of the superphosphate and potash, used separately, corn being valued at forty cents per bushel; but this increase is no greater on plot 8, where the superphosphate and potash are used in combination, than on plot 3, where potash only is used. Nitrate of soda has been used at a loss in the average, but the barnyard manure has certainly yielded a handsome profit.

FARM TEST IN WASHINGTON COUNTY.

Made by Orlando Trotter

Mr. Orlando Trotter, of Layman, Washington county, has made this test in 1891 and 1892, but on different land each time—a timothy sod in 1891 and a wheat stubble with one year's growth of clover in 1892. The land in both cases has been under cultivation for many years. The results of both experiments are given in table XXI.

TABLE XXI.—FERTILIZERS ON CORN IN WASHINGTON COU. TY.

1 bushel=70 pounds of ears.

Plot number.	Fertilizers.	Yield per acre.						Increase or decrease (—) per acre.						Plot number.
		Grain, bushels.			Stalks, pounds.			Grain, bushels.			Stalks, pounds.			
		1891.	1892.	Average.	1891.	1892.	Average.	1891.	1892.	Average.	1891.	1892	Average.	
1	None	33.9	28.3	31.1	1,731	2,780	2,255							1
2	Superphosphate	50 5	25.7	38.1	1,913	2,520	2,216	15.5	—2.0	6.7	252	—167	42	2
3	Muriate of potash	47.3	22.6	35.0	1,890	2,700	2,295	11.6	—4.6	3.5	300	107	203	3
4	None	37.3	26.6	31.9	1,520	2,500	2,010							4
5	Nitrate of soda	46.1	31.7	38 9	1,905	2,160	2,032	8.6	6.4	7.5	330	—267	31	5
6	Nitrate and superphosphate	51.2	41.4	46.3	1,771	2,860	2,315	13.5	17.5	15.5	141	507	324	6
7	None	37.9	22.6	30.2	1,685	2,280	1,982							7
8	Superphosphate and potash	47 2	21.4	34.3	1,970	2,640	2,305	7.9	—3.0	2.4	222	340	281	8
9	Nitrate and potash	47.8	43.1	45.4	1,850	2,640	2,245	7.1	16.9	12.0	40	320	180	9
10	None	42 1	28 0	35.0	1,873	2,340	2,106							10
11	Superphosphate, potash and nitrate	48.8	60 3	54.5	1,815	3,020	2,417	8.0	31.2	19.6	—11	647	318	11
12	Barnyard manure	48 0	37.1	42.5	1,962	2,680	2,321	8.6	6.8	7.7	184	273	228	12
13	None	38 1	31.4	34.7	1,731	2,440	2,085							13
14	Land plaster	48 9	26 6	37.7	1,892	2,520		10.8	—4.8	3.0	161	80	120	14
15	Bowker's superphosphate, 100 pounds		26.3			2,350			—5.1			—90		15
16	" " 200 "		25.0			2,630			—6.4			190		16
	Average of unfertilized plots	37.9	27.4		1,708	2,468								

The results of the two experiments are contradictory, so far as the apparent effect of superphosphate and potash is concerned. In 1891, on sod, every plot upon which these were used showed an increased yield of grain, even in the absence of nitrogen, while in 1892, on stubble, the results are in harmony with the average results at Columbus and in Columbiana county, in showing a loss of grain from the use of superphosphate or potash uncombined with nitrogen. Every plot treated with nitrate of soda, however, shows some increase of grain in both seasons, and this is the rule in all our experiments, although there are some exceptions, but the increase is seldom sufficient to pay the cost of the fertilizer.

CONCLUSIONS.

In almost every instance in all our field experiments on corn, an increase of crop has followed the use of nitrate of soda in combination with muriate of potash or superphosphate, one or the other, and it seems to make very little difference which, but the increase has frequently been reduced when both superphosphate and potash have been added to the nitrate.

In all our work with fertilizers, upon wheat and oats as well as corn, the effect of phosphoric acid seems to be chiefly shown in the stalk and straw. When plants are grown in selected soil in boxes, superphosphate, when used alone, produces a tall, pale, spindling growth of plant, and this may be observed to some extent in the field; but when nitrogen is added the color of the plant is immediately changed to dark green, the leaves appear broader and the entire plant manifests greater vigor.

Apparently, an excess of phosphoric acid stimulates the growth of stalk and straw at the expense of the grain, and thus in wheat the weight of straw may be increased and that of the grain at the same time diminished, while in corn both stalk and grain may be reduced by the less perfect development of leaf. This phenomenon has been manifested so frequently in our experiments that there is no longer room to doubt that *the yield of grain may be actually reduced by the use of fertilizers containing phosphoric acid or potash but no nitrogen.*

But it does not follow that the extensive purchase of nitrogen is necessary. A careful study of these experiments will show that nearly if not quite every case, in which a profitable increase of grain has followed the use of superphosphate without nitrogen, occurred either on sod or on soils which had been cropped in systematic rotation, whereby a good supply of decaying vegetation had been maintained; this decaying vegetation apparently furnishing the nitrogen required to balance the phosphoric acid added in the fertilizers.

It would seem, therefore, that if chemical fertilizers are to be used with any prospect of profit in the production of cereal crops it must be in connection with the culture of some nitrogen-storing crop, such as

clover, grown as frequently as possible in order to secure the greatest possible accumulation of vegetable matter in the soil; for at the present prices of fertilizers and cereal grains respectively it is a hopeless undertaking to attempt to supply, in chemical fertilizers, the quantity of phosphoric acid, potash and nitrogen, all three required to produce a crop or any increase in crop.

A bushel of Ohio grown wheat, with its straw, should contain about three-fourths of a pound of phosphoric acid, a pound of potash and a pound and three quarters of nitrogen. In a bushel of Ohio grown corn, with its stalks and cobs, may be found about three quarters of a pound of phosphoric acid, two-thirds of a pound of potash, and a pound and one-tenth of nitrogen.

At present prices of fertilizing materials in Ohio, the phosphoric acid and potash in a bushel of wheat would cost about 9 cents and the nitrogen about 33 cents, a total of 42 cents. The phosphoric acid and potash in a bushel of corn would cost about 8 cents and the nitrogen about 21 cents, total, 29 cents.

If, now, it were possible to recover in the crop all the fertilizing materials applied to the soil we might raise wheat and corn at a profit on purchased fertility; but this is not possible, for the soil is so constituted that it immediately seizes upon and converts into insoluble combinations a considerable proportion of the phosphoric acid and potash; while of the nitrogen, if applied as nitrate, a larger or smaller proportion, owing to the season, is sure to be washed out of the soil by rains. Thus, in the experiments at Rothamsted, where chemical fertilizers have been used continuously for fifty years, under the most favorable conditions less than half the phosphoric acid, potash or nitrogen applied in the fertilizer has been realized in the increase of crop, and in our experiments the return for the fertilizer is far below that of Rothamsted. The Rothamsted experiments show that a portion, at least, of the unused phosphoric acid and potash may be simply stored in the soil to be given up to future crops; but they also show that it will require many years of cropping, to get back all that has been given to the soil.

SUMMARY.

The experiments of this Station with fertilizers now include four years' continuous culture of wheat on the same land, with and without fertilizers, on the farm hitherto occupied by the Station in Columbus and belonging to the State University; three years' similar culture of wheat in Columbiana county; four years' continuous culture of oats on the Columbus farm; five years' continuous culture of corn on the Columbus farm and in Columbiana county, and fourteen co-operative experiments, made in 1889, 1890, 1891 and 1892 by farmers in Ashtabula, Holmes, Miami, Huron, Licking, Butler and Washington counties, besides several

years' study of crops grown in rotation and of plants grown in boxes.

These experiments must be continued farther before positive conclusions can be drawn, but at the present date the following tentative conclusions seem to be justified:

(1.) The use of superphosphate and potash, separately or in combination, but without nitrogen, has frequently caused a loss of grain in crops of corn and wheat on soils deficient in vegetable matter.

(2.) The yield of straw or stalks has almost invariably been increased by the use of superphosphate.

(3.) The use of superphosphate has frequently, and that of potash has occasionally been followed by a considerable increase of crop, both of grain and straw or stalks, on sod ground or land containing an abundance of decomposing vegetable matter.

(4.) An increase of grain in the crop has generally followed the use of nitrate of soda, and this has happened in almost every case when the nitrate has been used in combination with superphosphate or potash.

(5.) When a complete fertilizer has been used, containing both phosphoric acid and potash, in combination with nitrogen, the phosphoric acid being carried in less active forms than bone-black superphosphate, an increase of crop has resulted in practically every case; but at present prices of fertilizers and grain respectively, this increase has invariably cost more than its value in the market.

(6.) While, therefore, these experiments demonstrate the possibility of producing a regular and certain increase in the yield of cereal crops by the use of a complete chemical fertilizer, yet they show that if such fertilizers are to be used with any prospect of profit in Ohio in the production of cereal crops and as a part of a regular system of agriculture, that system must provide for the accumulation in the soil of the largest possible quantity of organic nitrogen, through the culture, in short rotations, of plants which have the power of obtaining nitrogen from sources inaccessible to the cereals.